Journal of Affective Disorders 174 (2015) 516–521

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Research report

Influence of depression on cardiometabolic responses to a lifestyle intervention in at-risk individuals

Adriana Cezaretto [a], Mohammadreza Pakseresht [b], Sangita Sharma [b], Fariba Kolahdooz [b], Antonela Siqueira-Catania [a], Camila Risso de Barros [a], Sandra Roberta Gouvea Ferreira [a,*]

[a] School of Public Health, Department of Nutrition, University of São Paulo, São Paulo, Brazil
[b] University of Alberta, Department of Medicine, Edmonton, Canada

ARTICLE INFO

Article history:
Received 25 November 2014
Received in revised form
9 December 2014
Accepted 11 December 2014
Available online 19 December 2014

Keywords:
Depression
Lifestyle intervention
Obesity
Cardiometabolic diseases

ABSTRACT

Background: Cardiometabolic diseases and depression are public health problems that are often related. The benefits of behavioral interventions on lifestyle are well documented. However, the influence of depression in these interventions is unclear.
Objective: To evaluate whether depression affects the impact of a lifestyle intervention on cardiometabolic response in an at-risk sample.
Methods: 129 individuals identified by the public health system to be at risk for cardiometabolic disease were allocated to 18-month interventions on diet and physical activity. Socio-demographic and clinical data were obtained. Depressive symptoms were assessed by the Beck Depression Inventory. Changes by at least 10% in each of 6 cardiometabolic risk factors were used to define responses to intervention. Logistic regression models were employed for each gender.
Results: Approximately 42% of individuals had depressive symptoms. They had higher adiposity, cholesterol, and blood pressure levels and lower quality of life and physical activity levels than non-depressed individuals. In adjusted models, only women with depression at baseline had lower chance of improving plasma glucose (OR: 0.32) and lower chance of improving mean blood pressure (OR: 0.29) after the follow-up, compared with non-depressed women.
Limitations: The small sample size may have diminished the power of the results and the instrument used to measure depression does not provide clinical diagnosis according to DSM criteria.
Conclusion: Depression at baseline of lifestyle interventions predicted a lower chance of improving long-term cardiometabolic risk, particularly in women, suggesting that screening and management of depression as part of lifestyle interventions can potentially improve cardiometabolic risk profile.

1. Introduction

Depression may affect quality of life (QoL) including social relationships, occupational productivity, and general well-being. Prospective studies have shown that even subclinical depression can impair health and interfere in daily living activities (Lecrubier, 2000; Spitzer et al., 1994). The worldwide prevalence rates for depression ranges from 0.8% to 9.6%, affecting a greater proportion of women than men (Demyttenaere et al., 2004; Simon, 2000). By 2030, depression is expected to be the leading cause of disease burden worldwide (Chisholm, 2006). Disease severity is inversely proportional to QoL (Strine et al., 2009) and directly linked to disability. Even mild depression reduces QoL and productivity this highlighting the importance of depression management (Lecrubier, 2000; Spitzer et al., 1994).

A substantial number of depressed patients are not appropriately diagnosed and treated despite frequently accessing primary health care services (Kessler et al., 2005; McQuaid et al., 1999). Their risk of coronary heart disease is high (Whang et al., 2009) and mortality rates are 1.8-fold greater than in the general population (Chang et al., 2010).

As a result of economic and technological progress, a number of lifestyle modifications among general population have taken place. These changes have contributed to an increase in cardiometabolic disturbances. It is generally accepted that changes in dietary habits and physical activity can reduce the risk associated with cardiometabolic diseases (Alberti et al., 2007; Tuomilehto et al., 2001). Difficulties of adherence to a healthy lifestyle may be partially explained by the presence of psychological disorders, such as depression. Associations between depression and cardiometabolic diseases such as obesity (Simon et al., 2008), type 2 diabetes

* Correspondence to: Departamento de Epidemiologia, Faculdade de Saúde Pública da Universidade de São PauloAv. Dr. Arnaldo, 715 – São Paulo, SP, Brasil – CEP 01246-904. Tel.: +55 11 3061 7870; fax: +55 11 3061 7926.
E-mail address: sandrafv@usp.br (S.R.G. Ferreira).

http://dx.doi.org/10.1016/j.jad.2014.12.037
0165-0327/

mellitus (T2DM) (Renn et al., 2011; Gois et al., 2012a, 2011) and others have been described. One in four individuals with T2DM has suffered from depression during their lifetime (Pouwer et al., 2006). Depressed individuals are 2.4 times more likely to develop metabolic syndrome than non-depressed individuals (Kahl et al., 2012). Coexistence of diseases increases morbidity, health care costs, and mortality (Bogner et al., 2007; Katon et al., 2009).

Inflammation could be the underlying mechanism involved with both depression and cardiometabolic diseases (Valkanova et al., 2013). Depression-induced activation of the hypothalamic–pituitary–adrenal axis increases cortisol secretion and enhances cortisol concentration. This contributes to the development of a pro-inflammatory state increasing abdominal obesity and insulin resistance, which in turn increases the risk of cardiometabolic diseases.

A lifestyle intervention for the prevention of T2DM was shown to improve emotional and physical aspects of QoL (Cezaretto et al., 2012). In addition, depressive symptoms decreased during follow-up, and individuals with reduced depression scores had the most metabolic benefit. However, whether the presence of depression at baseline of intervention programs influences cardiometabolic profile is unclear. This study evaluated whether depression affects the impact of a lifestyle intervention on cardiometabolic profile in a sample of the Brazilian population.

2. Material and methods

A total of 438 individuals aged 21 to 79 years, treated under the public health system of the São Paulo city, Brazil, between 2008 and 2010, were screened for T2DM using a locally developed questionnaire aiming to develop a prevention-based program. Those individuals who were found to be at risk were invited to a clinical examination and laboratory tests including a 75-g oral glucose tolerance test. Those with prediabetes (fasting glycemia between 100 and 125 mg/dL or 2-h glucose between 140 and 200 mg/dL) were invited to participate in the 18-month lifestyle intervention for diabetes prevention (www.fsp.usp.br/prevsm). Individuals with metabolic syndrome were considered for this study, since the presence of the condition has been associated with a 4.6-fold greater risk of T2DM (Ford et al., 2008; Gami et al., 2007). Individuals with a medical history of neurological or severe psychiatric disturbances, thyroid, liver, renal or infectious diseases were excluded. The Institutional Ethics Committee approved the study and written consent was obtained from all participants. This trial was registered (RBR #65N292) in the Brazilian registry center of the World Health Organization International Clinical Trials Registry Platform (www.ensaiosclinicos.gov.br).

For this study, 230 individuals were eligible and 183 agreed to participate in one of the two types of 18-month interventions on lifestyle. Ninety seven subjects were allocated to the interdisciplinary intervention and 86 to the traditional intervention (de Barros et al., 2013). Among those who refused to participate, there was a predominance of men; however, non-participants did not differ from participants in terms of baseline socio-demographic, anthropometric, metabolic variables, or average depression scores. The reasons for refusals were related to distance and timing as the intervention occurred during business hours. Of the 183 individuals enrolled, 129 completed the intervention (Fig. 1). Individuals who dropped out during the follow-up were younger than those who remained for the whole period (50.6 SD 12.9 *vs.* 56.3 SD 11.8 years, $p=0.006$).

The methodology of the two intervention plans was previously described elsewhere (Cezaretto et al., 2012; Siqueira-Catania et al., 2013). Briefly, the traditional intervention consisted of quarterly medical visits with an endocrinologist, in which participants received usual written guidelines for changing diet and physical activity, advocated by the Brazilian public health system. In addition to medical visits, the interdisciplinary intervention with the psychoeducational approach included an individual appointment with a nutritionist and 16 group sessions conducted by a multiprofessional team (endocrinologist, psychologist, nutritionist, and physical educator). The present analysis is based on a sample pooled from both the intervention groups. Results comparing clinical, behavioral, and psychological data between interventions have been described elsewhere (Cezaretto et al., 2012; Siqueira-Catania et al., 2013).

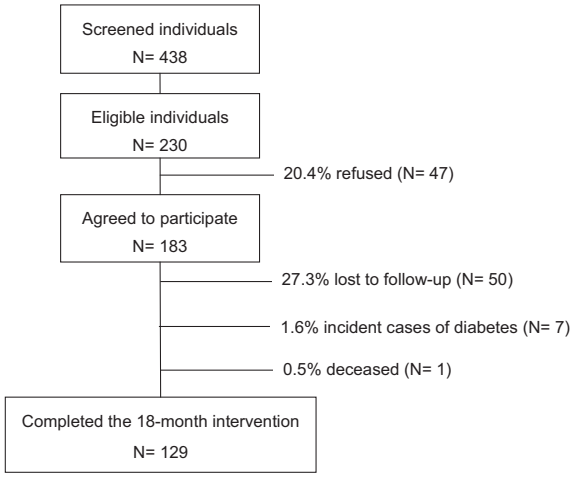

Fig. 1. Flowchart of individuals at each stage of the study.

Standardized questionnaires were used for studying socio-economic and general health status. Physical activity level was evaluated by utilizing long version of the International Physical Activity Questionnaire (Craig et al., 2013). Dietary habits were assessed using three 24-h recalls (two weekdays and one weekend day) and data was analyzed by using the Nutrition Data System for Research software (Nutrition Coordinating Center (NCC), 2005). Depression symptoms were assessed using the Beck Depression Inventory (BDI), of which depression scores ranged from between 0 and 63 (Beck et al., 1988) BDI scores greater than or equal to 12 were interpreted as indicating the presence of depression. QoL was assessed by the Medical Outcome Study 36-Item Short-Form Health Survey (Ware et al., 1998). This questionnaire includes eight QoL domains (physical function, physical role, bodily pain, general health, vitality, social functioning, emotional role, and mental health). The scores obtained were combined to calculate the SF-36 physical and mental component summaries. These health scales are scored from 0 to 100, indicating worse to better QoL, respectively (Ware et al., 1998).

Biochemical tests (*i.e.* plasma glucose, lipid profile, and adiponectin, C-reactive protein—CRP, and TNF-α) in conjunction with clinical examinations were performed at the study baseline and after 18 months of follow-up. Height was measured using a fixed stadiometer and weight was taken with individuals wearing light clothes and no footwear on a Filizola digital scale. Waist circumference was measured at the midpoint between the bottom of the rib cage and above the top of the iliac crest during minimal respiration. Blood pressure (BP) was measured at rest in a sitting position, three times with a five minute interval, using an automatic blood pressure device (Omron HEM-712C, Omron Health Care, USA). The average of the last two measurements was used in the analysis. Mean arterial blood pressure was calculated by the formula: "Systolic BP + (2 × Diastolic BP)/3".

2.1. Statistical analysis

Mean and standard deviation (SD) were reported for continuous variables including; depression scores, QoL, dietary intake,

physical activity, and clinical data. Nutrient value per 1000 kcal was calculated for dietary fiber and saturated fatty acid intakes (Stampfer et al., 2000). Normality of distributions was verified with histograms and Kolmogorov–Smirnov test. Student *t*-test (or non-parametric test) and chi-squared test were used to compare continuous and categorical variables, respectively, between depressed and non-depressed individuals at baseline. Any statistically significant difference of variables between the two study stages (at baseline and after 18 months follow-up) were examined by the paired *t*-test (or non-parametric tests).

Multiple logistic regressions were used to analyze the association between depression at baseline (independent variable) and changes in metabolic syndrome components (waist circumference, blood pressure levels, plasma glucose, triglycerides, and HDL-cholesterol) after interventions. As an extra outcome, "general improvement in cardiometabolic profile" was defined as changes in at least three out of these five components: $\geq 5\%$ decrease in waist circumference and/or BMI, $\geq 10\%$ decrease in mean blood pressure, $\geq 10\%$ decrease in either fasting or post-load glycemia, $\geq 10\%$ decrease in triglycerides, and $\geq 10\%$ increase in HDL-cholesterol. Depression was categorized using BDI scores < 12 and ≥ 12 for the absence and presence of depression, respectively. Forward stepwise multiple regression models were adjusted for age, sex, physical activity, and type of intervention, as well as for those variables selected based on univariate analyses (marital status, education, energy, fiber, and saturated fatty acid intake). In addition, inflammatory markers such as mediators of cardiometabolic profile, CRP, adiponectin, and TNF-α were added into the models. The likelihood ratio test (LRT) was employed to compare the results of a logistic regression model with interaction term and a logistic regression model without interaction term. When the *p* Value of LRT is less than 0.05, the LRT indicates that the baseline depression status impacts the intervention on cardiometabolic profiles.

For the analysis of baseline data, only individuals who completed the 18-months intervention were included. Considering the gender differences in depression experience and manifestations, the regression analyses were conducted for each gender independently.

Due to the possibility of false-positive results (type I errors) by conducting multiple pair wise significance tests on the study data, *p*-Values were considered statistically significant at $\alpha < 0.01$ for two-sided tests. Statistical analysis was performed using Stata, version 11 software.

3. Results

At baseline, the sample ($n=129$) predominantly consisting of women ($n=85$) with a mean age of 54.7 SD 12.3 years, while approximately half of the participants had ≤ 8 years of schooling and 41.9% exhibited depression symptoms.

On the stratified analysis, according to the presence of depression at baseline (Table 1), depression was more frequent among women. Depressed individuals spent less time on physical activity, had slightly higher BMI ($p=0.037$), and cholesterol values ($p=0.014$) than non-depressed individuals. Both mental and physical components of QoL were worse in subjects with depression.

Table 1
Baseline data of study participants, stratified according to the presence of depression.

	Depressed $n=54$	Non-depressed $n=75$	*p*-Value
Gender, *n* (%)			
Women ($n=85$)	45 (83.3)	40 (53.3)	
Men ($n=44$)	9 (16.7)	35 (46.7)	< 0.001
Marital status, *n* (%)			
Single	12 (22.2)	8 (10.7)	
Married	31 (57.4)	49 (65.3)	
Divorced or widowed	11 (20.4)	18 (24.0)	0.201
Schooling, n (%)			
≤ 8 years	34 (63.0)	33 (44.0)	
9 to 12 years	10 (18.5)	12 (16.0)	
> 12 years	10 (18.5)	30 (40.0)	0.031
Employment, *n* (%)			
Employee	16 (29.6)	34 (45.3)	
Housework or retired or unemployed	38 (70.4)	41(54.7)	0.071
Life habits			
Energy (kcal), mean (SD)	1677 (722)	1923 (628)	0.043
Saturated fatty acids (g/1000 kcal), mean (SD)	19.5 (12.1)	21.6 (11.2)	0.312
Dietary fiber (g/1000 kcal), mean (SD)	9.2 (3.5)	9.4 (3.9)	0.808
Physical activity (hours/week), mean (SD)	0.27 (0.63)	0.84 (1.26)	0.004[a]
Smoking, *n* (%)	6 (11.1)	5 (6.7)	0.525
Age (years), mean (SD)	54.5 (12.2)	57.4 (11.0)	0.153
Body mass index (kg/m^2), mean (SD)	31.3 (5.7)	29.6 (5.0)	0.037
Waist circumference (cm), mean (SD)	102.6 (13.9)	99.6 (12.4)	0.204
Systolic blood pressure (mmHg), mean (SD)	136.9 (23.0)	136.1 (18.3)	0.836
Diastolic blood pressure (mmHg), mean (SD)	85.0 (12.9)	80.9 (9.8)	0.045
Mean blood pressure (mmHg), mean (SD)	102.3 (14.9)	99.3 (10.7)	0.192
Fasting plasma glucose (mg/dL), mean (SD)	98.3 (12.7)	99.5 (10.9)	0.560
Post-load plasma glucose (mg/dL), mean (SD)	121.9 (29.2)	116.9 (27.7)	0.323
Triglycerides (mg/dL), mean (SD)	159.2 (67.0)	154.1 (66.3)	0.640[a]
Cholesterol total (mg/dL), mean (SD)	214.3 (45.2)	195.3 (40.8)	0.014
LDL-cholesterol (mg/dL), mean (SD)	139.1 (43.4)	121.4 (36.3)	0.014
HDL-cholesterol (mg/dL), mean ((SD)	42.2 (11.8)	42.7 (12.9)	0.820
Adiponectin (μg/mL), mean (SD)	16.3 (17.9)	14.6 (12.7)	0.890[a]
C-reactive protein (mg/mL), mean (SD)	0.35 (0.26)	0.34 (0.24)	0.938[a]
Tumor necrosis factor-α (pg/mL), mean (SD)	12.8 (7.4)	12.2 (5.5)	0.867[a]
Quality of life, mean(SD)			
Physical component summary	45.8 (10.2)	51.5 (7.0)	< 0.001
Mental component summary	39.7 (10.7)	49.0 (10.9)	< 0.001

[a] Analysis using Mann Whitney test.

Post-intervention energy and saturated fat intake were significantly lower than baseline (Table 2). These changes were accompanied by reduced body adiposity, blood pressure, and increased HDL-cholesterol concentrations. QoL and depression scores improved significantly after interventions. In a multiple linear model, post-load plasma glucose levels were higher (9 mg/dL) after intervention among women with depression than those without depression (data not shown).

On fully adjusted multiple regression analysis (Table 3), a general improvement in cardiometabolic profile was not associated with the presence of depression at baseline. However, in specific models developed for each of the cardiometabolic profile components, depressed women at baseline had a 68% lower chance of improving plasma glucose levels than non-depressed women. Reduced body adiposity levels ($\geq$ 5% reduction in BMI and/or waist circumference) as an independent variable in this model, contributed significantly to an increase in the chance of improving glycemia (OR 3.71). In the blood pressure model, depressed women had a 71% lower chance of reducing mean blood pressure (by $\geq$ 10%) at 18 months, compared to non-depressed women. An indirect link between education and blood pressure improvement was observed only for men. No association was found between baseline depression status and other outcomes (improvement in body adiposity or serum levels of triglycerides and HDL-cholesterol) after 18 months of intervention. Inclusion of inflammatory markers into the models did not influence the association between depression and improvement in cardiometabolic profile.

No differences in results were found after comparing models with or without the interaction variable (depression × interdisciplinary intervention). The LRT showed that the interdisciplinary intervention did not influence the association of depression with lack of glycemia improvement ($p=0.12$) and blood pressure ($p=0.13$) observed among the women.

Table 2
Dietary, clinical and psychological data at baseline and after interventions, expressed as mean (SD).

	Baseline	Post-intervention	*p*-Value
Energy (kcal)	1811 (716)	1543 (540)	< 0.001[a]
Saturated fatty acids (g/1000 kcal)	20.6 (11.5)	17.3 (9.3)	< 0.001[a]
Dietary fiber (g/1000 kcal)	9.1 (4.1)	10.2 (4.3)	0.030
Physical activity (hours/week)	0.63 (1.12)	0.78 (1.35)	0.361[a]
Body mass index (kg/m^2)	30.8 (5.8)	29.6 (5.5)	< 0.001
Waist circumference (cm)	101.2 (12.8)	98.5 (12.4)	< 0.001
Systolic blood pressure (mmHg)	136.1 (19.1)	129.6 (17.4)	< 0.001
Diastolic blood pressure (mmHg)	82.8 (10.9)	77.5 (8.9)	< 0.001
Mean blood pressure (mmHg)	100.5 (11.9)	94.9 (10.1)	< 0.001
Fasting plasma glucose (mg/dL)	99.3 (11.5)	97.2 (14.4)	0.108
Post-load glycemia (mg/dL)	118.3 (27.4)	117.5 (39.8)	0.343
Triglycerides (mg/dL)	150.9 (68.9)	148.5 (80.1)	0.067[a]
Total cholesterol (mg/dL)	199.1 (42.3)	199.5 (43.0)	0.377
LDL-cholesterol (mg/dL)	126.0 (38.6)	121.4 (39.4)	0.032
HDL-cholesterol (mg/dL)	42.2 (11.7)	49.3 (14.4)	< 0.001
Adiponectin (μg/mL)	14.7 (13.5)	18.9 (11.3)	< 0.001[a]
C-reactive protein (mg/mL)	0.32 (0.25)	0.04 (0.05)	0.001[a]
Tumor necrosis factor-α (pg/mL)	12.5 (6.7)	10.4 (6.8)	< 0.001[a]
Physical component of QoL	48.7 (8.9)	52.6 (7.5)	< 0.001
Mental component of QoL	44.4 (12.6)	50.6 (10.1)	< 0.001
Depression score between 0 and 63	11.9 (9.9)	5.8 (6.3)	< 0.001[a]

[a] Pairwise analysis by Wilcoxon signed-rank test.

4. Discussion

This study expands on previous research by investigating the influence of pre-existing depression symptoms on cardiometabolic response to a lifestyle intervention in at-risk Brazilians. We confirmed that women were more frequently depressed than men and depressed women may have a lower chance of improving blood pressure and glycemia during the intervention program than non-depressed women. Depression is known to facilitate both unhealthy habits and non-adherence to medical recommendations (Cassano and Fava, 2002). Depression also is an important risk factor for cardiovascular morbidity and mortality (Huffman et al., 2013). Our results reinforced the importance of depression screening and management, especially among women, when conducting lifestyle interventions for the prevention of cardiometabolic diseases.

Taking the entire sample and composite of outcomes together, a deleterious role of depression on the response to the lifestyle intervention was not suggested in our study. Only when stratifying by sex and considering isolated components of the metabolic

Table 3
Logistic regression analyses for association between depression at baseline and intervention-induced improvement in cardiometabolic outcomes, adjusted for baseline variables.

	Total		Women		Men	
	OR	95% CI	OR	95% CI	OR	95% CI
General improvement in cardiometabolic profile[a]						
Depression at baseline (BDI $\geq$ 12)	0.91	0.41;2.01	0.76	0.29;1.98	1.78	0.35;9.18
Adiponectin (μg/mL)	0.99	0.97;1.02	0.99	0.96;1.03	0.99	0.92;1.07
Interdisciplinary intervention	1.10	0.51;2.36	0.94	0.35;2.52	0.93	0.23;3.76
Plasma glucose improvement[b]						
Depression at baseline (BDI $\geq$ 12)	0.45	0.19;1.03	0.32	0.12;0.87	3.59	0.44;29.4
Adiponectin (μg/mL)	1.02	0.99;1.06	1.01	0.97;1.05	1.06	0.95;1.18
Interdisciplinary intervention	0.53	0.24;1.17	0.46	0.17;1.28	0.50	0.11;2.35
Outcome: Blood pressure improvement[c]						
Depression at baseline (BDI $\geq$ 12)	0.51	0.20;1.34	0.29	0.10;0.94	81.7	0.87;769.8
TNF-α (pg/mL)	0.98	0.92;1.04	0.98	0.92;1.06	0.91	0.66;1.27
Educated	0.75	0.44;1.28	0.91	0.45;1.85	0.21	0.04;0.96
Interdisciplinary intervention	5.07	2.01;12.7	8.05	2.32;27.9	2.57	0.22;29.8
Body adiposity (at least ↓10%)	4.01	1.33;12.1	4.17	0.91;19.0	0.89	0.06;13.1

All models adjusted by age, physical activity and energy.

[a] Improvement on at least 3 out of 5 measures of metabolic syndrome components (Body, Glycemia, Blood Pressure, Triglycerides and/or HDL-cholesterol).
[b] Improvement on at least 10% on fasting or post-load glycemia after follow-up.
[c] Improvement on at least 10% on mean blood pressure.

syndrome, a deleterious effect of depression to lifestyle intervention has been suggested.

In accordance with our finding, it is commonly reported that women are more likely than men to be affected by depression (Demyttenaere et al., 2004; Simon, 2000; Moldin et al., 1993). Moreover, studies have shown that women with cardiovascular diseases are more likely to suffer from depression than men with the same condition (Möller-Leimkühler, 2010). Women with major depressive episode were shown to be twice as likely to have metabolic syndrome compared to women without the condition, but not men without the condition (Kinder et al., 2004). Hormonal and psychological factors may explain this phenomenon (Rubinow et al., 1998; Wright et al., 2014). A severe form of premenstrual syndrome was linked to depressive symptoms. An association between estrogen and serotonin, a hormone responsible for mood regulation, was also described (Rubinow et al., 1998). In addition, daily stress, such as commuting to work, child care and everyday chores may render women more prone to depression. Unhealthy lifestyles (increased energy and saturated fat intakes and physical inactivity) enhance the risk of obesity and comorbidities, which are more commonly found among depressed women (Wronka et al., 2013). However, one study reported that metabolic syndrome was associated with depression only in males (Gil et al., 2006). In spite of some contradictory results, depression *per se* may lead to an increase in cardiovascular risk. Our study further found that depressed women participated in lifestyle interventions also had a lower chance of improving on components of the metabolic syndrome (plasma glucose and blood pressure levels).

Association between depression and diabetes mellitus is well documented and a bidirectional association has been proposed (Pan et al., 2010). Depression seems to increase the risk for diabetes onset (Chen et al., 2013; Gois et al., 2012b) and the presence of depression may lead to a more severe diabetes status (Doyle et al., 2013). Along the same lines, in our study, the presence of depression decreased the chance of improving glycemic levels in women, even after adjusting for body adiposity, whose reduction was strongly associated with plasma glucose improvement. A recent study is in concordance with our investigation in that high hemoglobin A1C over time was predicted by the presence of depression (Musselman et al., 2014).

In our study, depression also had a deleterious impact on blood pressure response to the intervention, which is another major cardiovascular risk factor. Other authors had previously shown that depressed individuals have a higher risk for developing hypertension (Yan et al., 2003). The biological plausibility for this association may be depression-induced adrenergic hyperactivity resulting in blood pressure elevation (Yeragani et al., 1995; Davidson et al., 2000). In agreement, a cohort study found that depression symptoms were predictive of hypertension after 5 years of follow-up (Davidson et al., 2000). Further meta-analysis reinforced that depression increases the risk of hypertension (Meng et al., 2012).

Another pathway that could explain associations of depression with components of the metabolic syndrome is a pro-inflammatory status. Several studies have identified subclinical inflammation as an intermediate pathway among depression, obesity, T2DM and hypertension (Valkanova et al., 2013). However, our results failed to support this hypothesis because inflammatory markers did not influence the association between depression and cardiometabolic responses in multiple regression models. Our findings are similar to some (Soderlund et al., 2011; McDade et al., 2013) but in disagreement with other studies (Valkanova et al., 2013; Huffman et al., 2013).

We also examined the association between depressive status and cardiometabolic outcomes. However, we were unable to demonstrate its association with general improvement in cardiometabolic profile. This lack of association was previously described in a Finnish cohort study in which no clear relationship between depression and metabolic syndrome was found (Herva et al., 2006). On the other hand, two meta-analyses indicated the existence of this association (Pan et al., 2010; Nabe et al., 2008).

The strength of the present study is its longitudinal nature, which allowed for assessment of the influence of depression on cardiometabolic risk over time. However, the study has a number of limitations. Owing to its longitudinal nature, it was hard to ensure compliance during 18 months of follow-up. While 71% is an acceptable completion rate considering the difficulties outlined, the small sample size may have diminished the power of the results in relation to men in the sex stratified analysis. The instrument used to measure depression does not provide clinical diagnosis according to CID 10 or DSM-IV criteria. Nevertheless, studies have demonstrates that even subclinical depression may decrease QoL and increase morbidity and mortality, especially in individuals with other medical illnesses (Lecrubier, 2000; Spitzer et al., 1994).

In summary, depression at baseline of a lifestyle intervention may predict a lower chance of improving long-term cardiometabolic profile particularly among women. This points to the need raising the awareness of health professionals and public health policy makers' with regard to depressed individuals at high cardiometabolic risk. We suggest focusing on screening and management of depression as part of the intervention programs for lifestyle changes in at-risk individuals.

Role of funding source

This study was supported by São Paulo Foundation for Research Support – FAPESP, Sao Paulo, Brazil, with a Doctorate Scholarship (Process number: 11/06376-7) and a Research Internships Abroad linked to Doctorate (Process number: 13/03430-6) for Adriana Cezaretto and; a grant to Research for Sandra RG Ferreira (Process number: 07/55120-0).

The FAPESP had no involvement in the manuscript written process, study design or on data collection.

Conflict of interest

All the authors declare that there are no potential conflicts of interest.

Acknowledgments

FAPESP to provide funding for a student (Adriana Cezaretto) and for a researcher (Sandra Roberta G. Ferreira), post-graduation Program in Public Health of Nutrition, in School of Public Health, University of Sao Paulo. Aboriginal and Global Health Research Group, Division of Endocrinology & Metabolism, Department of Medicine, Faculty of Medicine & Dentistry, University of Alberta, Edmonton, AB, Canada.

References

Alberti, K.G., Zimmet, P., Shaw, J., 2007. International Diabetes Federation: a consensus on type 2 diabetes prevention. Diabet. Med. 24, 451–463.

Beck, A.T., Steer, R.A., Garbin, M.G., 1988. Psychometric properties of the Beck Depression Inventory: twenty-five years of evaluation. Clin. Psychol. Rev. 8, 77–100.

Bogner, H.R., Morales, K.H., Post, E.P., Bruce, M.L., 2007. Diabetes, depression, and death: a randomized controlled trial of a depression treatment program for older adults based in primary care (PROSPECT). Diabetes Care. 30, 3005–3010.

Cassano, P., Fava, M., 2002. Depression and public health: an overview. J. Psychosom. Res. 53, 849–857.

Cezaretto, A., Siqueira-Catania, A., de Barros, C.R., Salvador, E.P., Ferreira, S.R., 2012. Benefits on quality of life concomitant to metabolic improvement in intervention program for prevention of diabetes mellitus. Qual. Life Res. 21, 105–113.

Chang, C.K., Hayes, R.D., Broadbent, M., Fernandes, A.C., Lee, W., Hotopf, M., Stewart, R., 2010. All-cause mortality among people with serious mental illness (SMI), substance use disorders, and depressive disorders in southeast London: a cohort study. BMC Psychiatry 10, 1–7.

Chen, P.C., Chan, Y.T., Chen, H.F., Ko, M.C., Li, C.Y., 2013. Population-based cohort analyses of the bidirectional relationship between type 2 diabetes and depression. Diabetes Care 36, 379–382.

Chisholm, D., 2006. Dollars, DALYs and Decisions: Economic Aspects of the Mental Health System. World Health Organization Press, Geneva.

Craig, C.L., Marshall, A.L., Sjostrom, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt, M., Ekelund, U., Yngve, A., Sallis, J.F., Oja, P., 2013. International physical

activity questionaaire: 12-country reliability and validity. Med. Sci. Sports Exerc. 35, 1381–1395.
Davidson, K., Jonas, B.S., Dixon, K.E., Markovitz, J.H., 2000. Do depression symptoms predict early hypertension incidence in young adults in the CARDIA study? Coronary Artery Risk Development in Young Adults. Arch. Intern. Med. 160, 1495–1500.
de Barros, C.R., Cezaretto, A., Salvador, E.P., dos Santos, T.C., Siqueira-Catania, A., Ferreira, S.R., 2013. Implementation of a structured healthy lifestyle program to reduce cardiometabolic risk. Arq. Bras. Endocrinol. Metabol. 57, 7–18.
Demyttenaere, K., Bruffaerts, R., Posada-Villa, J., Gasquet, I., Kovess, V., Lepine, J.P., Angermeyer, M.C., Bernet, S., de Girolamo, G., Morosini, P., Polidori, G., Kikkawa, T., Ono, Y., Takeshima, T., Uda, H., Karam, E., Fayyad, J., Karam, A.N., Mneimneh, Z., Medina-Mora, M.E., Borges, G., Lara, C., de Graaf, R., Ormel, J., Gureje, O., Shen, Y., Huang, Y., Zhang, M., Alonso, J., Haro, J.M., Vilagut, G., Bromet, E.J.G.S., Webb, C., Kessler, R.C., Merikangas, K.R., Anthony, J.C., Von Korff, M.R., Wang, P.S., Brugha, T. S., Aguilar-Gaxiola, S., Lee, S., Heeringa, S., Pennell, B.E., Zaslavsky, A.M., Ustun, T.B., Chatterji, S., WHO World Mental Health Survey Consortium, 2004. Prevalence, severity, and unmet need for treatment of mental disorders in the World Health Organization World Mental Health Surveys. JAMA 291, 2581–2590.
Doyle, T.A., de Groot, M., Harris, T., Schwartz, F., Strotmeyer, E.S., Johnson, K.C., Kanaya, A., 2013. Diabetes, depressive symptoms, and inflammation in older adults: results from the health, aging, and body composition study. J. Psychosom. Res. 75, 419–424.
Ford, E.S., Schulze, M.B., Pischon, T., Bergmann, M.M., Joost, H.G., Boeing, H., 2008. Metabolic syndrome and risk of incident diabetes: findings from the European Prospective Investigation into Cancer and Nutrition-Potsdam Study. Cardiovasc. Diabetol. 7, 1–20.
Gami, A.S., Witt, B.J., Howard, D.E., Erwin, P.J., Gami, L.A., Somers, V.K., Montori, V.M., 2007. Metabolic syndrome and risk of incident cardiovascular events and death: a systematic review and meta-analysis of longitudinal studies. J. Am. Coll. Cardiol. 49, 403–414.
Gil, K., Radzillowicz, P., Zdojewski, T., Pakalska-Korcala, A., Chwojnicki, K., Piwonski, J., Ignaszewska-Wyrzykowska, A., Zaluga, K., Mielczarek, M., Landowski, J., Wyrzykowski, B., 2006. Relationship between the prevalence of depressive symptoms and metabolic syndrome. Results of the SOPKARD project. Kardiol. Pol. 64, 464–469.
Gois, C., Akiskal, H., Akiskal, K., Figueira, M.L., 2012a. The relationship between temperament, diabetes and depression. J. Affect. Disord. 142, S67–S71.
Gois, C., Aksikal, H., Akiskal, K., Figueira, M.L., 2012b. Depressive temperament, distress, psychological adjustment and depressive symptoms in type 2 diabetes. J. Affect. Disord. 143, 1–4.
Gois, C., Barbosa, A., Ferro, A., Santos, A.L., Sousa, F., Akiskal, H., Askiskal, K., Figueira, M.L., 2011. The role of affective temperaments in metabolic control in patients with type 2 diabetes. J. Affect. Disord. 134, 52–58.
Herva, A., Räsänen, P., Miettunen, J., Timonen, M., Läksy, K., Veijola, J., Laitinen, J., Ruokonen, A., Joukamaa, M., 2006. Co-occurrence of metabolic syndrome with depression and anxiety in young adults: the Northern Finland 1966 Birth Cohort Study. Psychosom. Med. 68, 213–216.
Huffman, J.C., Celano, C.M., Beach, S.R., Motiwala, S.R., Januzzi, J.L., 2013. Depression and cardiac diseases: epidemiology, mechanisms, and diagnosis. Cardiovasc. Psychiatry Nuerol. 2013, 1–14.
Kahl, K.G., Greggersen, W., Schweiger, U., Cordes, J., Balijepalli, C., Losch, C., Moebus, S., 2012. Prevalence of the metabolic syndrome in unipolar major depression. Eur. Arch. Psychiatry Clin. Neurosci. 262, 313–320.
Katon, W., Russo, J., Lin, E.H., Heckbert, S.R., Ciechanowski, P., Ludman, E.J., Von Korff, M., 2009. Depression and diabetes: factors associated with major depression at five-year follow-up. Pyschosomatics 50, 570–579.
Kessler, R.C., Chiu, W.T., Demler, O., Merikangas, K.R., Walters, E.E., 2005. Prevalence, severity, and comorbidity of 12-month DSM-IV disorders in the National Comorbidity Survey Replication. Arch. Gen. Psychiatry 62, 617–627.
Kinder, L.S., Carnethon, M.R., Palaniappan, L.P., King, A.C., Fortmann, S.P., 2004. Depression and the metabolic syndrome in young adults: findings from the third national health and nutrition examination survey. Psychosom. Med. 66, 316–322.
Lecrubier, Y., 2000. Depressive illness and disability. Eur. Neuropsychopharmacol. 10, S439–S443.
McDade, T.W., Borja, J.B., Adair, L.S., Kuzawa, C., 2013. Depressive symptoms are not associated with inflammation in younger and older adults in the Philippines. Evol. Med. Public Health 2013, 18–23.
McQuaid, J.R., Stein, M.B., Laffaye, C., McCahill, M.E., 1999. Depression in a primary care clinic: the prevalence and impact of an unrecognized disorder. J. Affect. Disord. 55, 1–10.
Meng, L., Chen, D., Yang, Y., Zheng, Y., Hui, R., 2012. Depression increases the risk of hypertension incidence: a meta-analysis of prospective cohort studies. J. Hypertens. 30, 842–851.
Moldin, S.O., Scheffner, W.A., Rice, J.P., Nelson, E., Knesevich, M.A., Akiskal, H., 1993. Association between major depressive disorder and physical illness. Psychol. Med. 23, 755–761.
Möller-Leimkühler, A.M., 2010. Higher comorbidity of depression and cardiovascular disease in women: a biopsychosocial perspective. World J. Biol. Psychiatry 11, 922–933.
Musselman, D.L., Ziemer, D.C., McNutt, M.D., Seay, J.S., Royster, E.B., Larsen, B., Barham, T., Brown, A.R., Vogel, O.L., Phillips, L.S., Harvey, P.D., 2014. Depression, deficits in functional capacity, and impaired glycemic control in urban African Americans with type 2 diabetes. J. Psychiatry Res. 52, 21–27.
Nabe, K., Nomura, K., Ikeda, H., Honjo, S., Wada, Y., Kinura, T., Aoyama, T., Hamamoto, Y., Koshiyama, H., 2008. Depression is a component of the metabolic syndrome. Med. Hypotheses Res. 4, 79–83.
Nutrition Coordinating Center (NCC), 2005. Nutrition Data System for Research-NDS-R. University of Minnesota, Minneapolis.
Pan, A., Lucas, M., Sun, Q., van Dam, R.M., Franco, O.H., Manson, J.E., Willett, W.C., Ascherio, A., Hu, F.B., 2010. Bidirectional association between depression and type 2 diabetes mellitus in women. Arch. Intern. Med. 170, 1884–1891.
Pouwer, F., Beekman, A.T., Lubach, C., Snoek, F.J., 2006. Nurses' recognition and registration of depression, anxiety and diabetes-specific emotional problems in outpatients with diabetes mellitus. Patient Educ. Couns. 60, 235–240.
Renn, B.N., Feliciano, L., Segal, D.L., 2011. The bidirectional relationship of depression and diabetes: a systematic review. Clin. Psychol. Rev. 31, 1239–1246.
Rubinow, D.R., Schmidt, P.J., Roca, C.A., 1998. Hormone measures in reproductive endocrine-related mood disorders: diagnostic issues. Psychopharmacol. Bull. 34, 289–290.
Simon, G.E., 2000. Long-term prognosis of depression in primary care. Bull. World Health Organ. 78, 439–445.
Simon, G.E., Ludman, E.J., Linde, J.A., Operskalski, B.H., Ichikawa, L., Rohde, P., Finch, E.A., Jeffery, R.W., 2008. Association between obesity and depression in middle-aged women. Gen. Hosp. Psychiatry 30, 32–39.
Siqueira-Catania, A., Cezaretto, A., Barros, C.R., Salvador, E.P., Carvalho, T., Ferreira, S.R., 2013. Cardiometabolic risk reduction through lifestyle intervention programs in the Brazilian public health system. Diabetol. Metab. Syndr. 5, 21–27.
Soderlund, J., Olsson, S.K., Samuelsson, M., Walther-Jallow, L., Johansson, C., Erhardt, S., Landén, M., Engberg, G., 2011. Elevation of cerebrospinal fluid interleukin-1β in bipolar disorder. J. Psychiatry Neurosci. 36, 114–118.
Spitzer, R.L., Williams, J.B., Kroenke, K., Linzer, M., deGruy, F.V.I., Hahn, S.R., Brody, D., Johnson, J.G., 1994. Utility of a new procedure for diagnosing mental disorders in primary care. The PRIME-MD 1000 study. JAMA (272), 1749–1756.
Stampfer, M.J., Hu, F.B., Manson, J.E., Rimm, E.B., Willett, W.C., 2000. Primary prevention of coronary heart disease in women through diet and lifestyle. N. Engl. J. Med. 343, 16–22.
Strine, T.W., Kroenke, K., Dhingra, S., Balluz, L., Gonzalez, O., Berry, J.T., Mokdad, A.H., 2009. The associations between depression, health-related quality of life, social support, life satisfaction, and disability in community-dwelling US adults. J. Nerv. Ment. Dis. 197, 61–64.
Tuomilehto, J., Lindstrom, J., Eriksson, J.G., Valle, T.T., Hamalainen, H., Ilanne-Parikka, P., Keinanen-Kiukaanniemi, S., Laakso, M., Louheranta, A., Rastas, M., Salminen, V., Aunola, S., Cepaitis, Z., Moltchanov, V., Hakumaki, M., Mannelin, M., Martikkala, V., Sundvall, J., Uusitupa, M., Finnish Diabetes Prevention Study Group, 2001. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. N. Engl. J. Med. 344, 1343–1350.
Valkanova, V., Ebmeier, K.P., Allan, C.L., 2013. CRP, IL-6 and depression: a systematic review and meta-analysis of longitudinal studies. J. Affect. Disord. 150, 736–744.
Ware, J.E.J., Kosinski, M., Gandek, B., Aaronson, N.K., Apolone, G., Bech, P., Brazier, J., Bullinger, M., Kaasa, S., Leplege, A., Prieto, L., Sullivan, M., 1998. The factor structure of the SF-36 Health Survey in 10 countries: results from the IQOLA Project. International Quality of Life Assessment. J. Clin. Epidemiol. 51, 1159–1165.
Whang, W., Kubzansky, L.D., Kawachi, I., Rexrode, K.M., Kroenke, C.H., Glynn, R.J., Garan, H., Albert, C.M., 2009. Depression and risk of sudden cardiac death and coronary heart disease in women: results from the Nurses' Health Study. J. Am. Coll. Cardiol. 53, 950–958.
Wright, L., Simpson, W., Van Leishout, R.J., Steiner, M., 2014. Depression and cardiovascular disease in women: is there a common immunological basis? A theoretical synthesis. Ther. Adv. Cardiovasc. Dis. 8, 56–69.
Wronka, I., Suliga, E., Pawliñska-Chmara, R., 2013. Evaluation of lifestyle of underweight, normal weight and overweight young women. Coll. Antropol. 37, 359–365.
Yan, L.L., Liu, K., Matthews, K.A., Daviglus, M.L., Ferguson, T.F., Kiefe, C.I., 2003. Psychosocial factors and risk of hypertension: the Coronary Artery Risk Development in Young Adults (CARDIA) study. JAMA 290, 2138–2148.
Yeragani, V.K., Balon, R., Pohl, R., Ramesh, C., 1995. Depression and heart rate variability. Biol. Psychiatry 38, 768–770.